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28 June 1969

MEMORANDUM

To:

Subj: Information to Supplement Proposal

I. Task Abstract

calls for the continuation of the program of research in computerized image processing for a period of three months. Primary emphasis will be placed on basic restoration investigations to define quantitatively the expectations for successful processing of motion and defocus degraded imagery in high resolution systems. Processing of real imagery degraded by linear image motion will be done, starting with 20 line per millimeter resolution and working upward toward the goal of 100 lines per millimeter. Studies will also be directed toward a determination of the effectiveness of dual gamma processing as an image restoration technique and to determine the extent to which adjacency limits the successful application of computerized image processing. Software support in the form of additional programs will be supplied to satisfy the needs as they are developed in the course of the research. No new equipment development will be undertaken. The final repackaging of the new refresh display system will receive a small amount of effort.

II. Introduction

The has been conducting, under funding from the Central Intelligence Agency a continuing program of research in the restoration of degraded photographic images by means of computer processing. Funding in response to Proposal covered a 3-month period ending 1 July 1969. The present proposal calls for a continuation of the effort from 1 July 1969, to 1 October 1969. The following is a brief description of the status of the several tasks which have received effort in the course of this research program.

Task 1: On-Line Computer Operation. The research program utilizes an IBM-1800 computer which is leased with the cost equally shared by the Central Intelligence Agency and the Advanced Research Projects Agency. sometimes finds it efficient to utilize time on the IBM-1800 when available, for work on other Laboratory contracts or grants. When this is done, the appropriate cost of that time is recharged to the contract or grant involved.

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Substantial progress has been made in achieving flexible and efficient software for performing the image processing research. The utilization of the computer has been dramatically increased by the development of an unattended night operation in which the computer receives its instructions from cards rather than the keyboard. The instructions are still given in the language of image processing, and techniques have been developed such that the cards are easy to prepare.

The unattended card mode of operation has been supplemented by the addition of a 35mm [redacted] camera whose shutter and film advance mechanisms are computer controlled. This allows pictures to be made during all-night runs.

A very recent development tremendously enhances the ability to make parametric studies in the unattended mode of operation. In a parametric study, there is usually a sequence of operations which is repeated many times with one or more important parameters incremented during each repetition. The new software allows the operator to advise the computer that he desires the computer to memorize a sequence of operations which he then enters. He also indicates the starting values and increments for each parameter and the number of times the sequence is to be run. In this way a very small number of cards of instructions, taking only minutes to prepare is all that is required to handle calculations lasting many hours. Coupled with the [redacted] camera, runs involving 40 hours of computation and producing 600 output pictures have been made on weekends.

Task 2: Equipment Engineering. Under the present funding effort has been directed toward improved display capability. As explained in Proposal [redacted] 18 April 1968, the level of funding provided in response to that proposal did not permit full exploitation of the concepts of improved display systems which have evolved during the course of the research. Nevertheless, the recirculating or refresh display system has been achieved. In this equipment an image can be loaded into a small core memory which is an integral part of the display unit. This core memory is then scanned repetitively at TV type frame rates and displayed on a cathode-ray-tube for direct viewing. This provides a flicker-free presentation not requiring photographic recording. An exploratory unit has been constructed and operated.

Supplementary circuitry has been constructed for the refresh display which provides what is called inner-raster-scan. The inner-raster-scan reduces the distracting discreteness of the displayed images by spreading the flux from a single data point over the region between data points in a controlled way. The particular weighting of the flux distribution is programmable. It is presently

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being operated in a mode which is equivalent to providing two-dimensional linear interpolation between data points. Preliminary results show substantial improvements in the appearance of the images. The inner-raster-scan is presently operable in a slow scan photographic recording mode because the circuitry will not allow the high scan rates which would be required for the direct view mode of operation.

Testing of the refresh display has been completed and the repackaging of the system for use with the computer is nearing completion.

Other equipment developments are being funded by the Advanced Research Projects Agency. Although they are not being paid for by the Central Intelligence Agency, they will be used for the Central Intelligence Agency research program at the [redacted] These equipments include an image dissector film scanner and a microscope flying spot scanner. The image dissector now exists in breadboard form and the microscope flying spot scanner is now under construction. These all-electronic scanners offer the advantage of putting the film scanning operations under computer control so that the operator can position the scan and choose the step size and array size at will. During these operations the scanning will be at TV rates to provide direct viewing on a c.r.t. display. The scan speed would be reduced for actual data taking to maximize the signal-to-noise ratio.

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Task 3: Basic Restoration Investigations. The basic theoretical and experimental studies of optimum restoration techniques have been continued. Exciting progress has been made in non-Fourier techniques of image processing. These explorations have included extensions of the non-negative algorithm previously described, the application of linear programming, and an algorithm involving Baye's theorem. Each of these techniques have the inherent ability to utilize a'priori constraints on the image restoration, as for example, boundaries on the object of interest and non-negative luminance or brightness values. Preliminary studies have produced results which appear, in some cases, to be considerably better than Fourier processing of the same images. All three techniques are at present time consuming with respect to the Fourier techniques.

Defocus degradations have received considerable attention. Laboratory photographs intentionally defocussed have been scanned and successfully restored. These first experiments have involved large amounts of defocus, i. e., low resolution photography where the film granularity situation is favorable. Experimental studies of defocus point spread functions for a [redacted] camera have been made and it has been found that results are not in agreement with general defocus theory reported in the open literature. Explanations of this discrepancy would be greatest for small amounts of defocus and with high resolution, it is important to resolve this discrepancy prior to attempting image restoration on high resolution photography.

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Image motion studies are presently underway. Restorations have been successfully performed on low resolution photography. High resolution restoration experiments will be made in the near future.

A technique known as "sanding" has been developed. This technique is based on the realization that when an image is degraded the spatial derivations of the image are reduced. A high value for a spatial derivation in a degraded image is probably due to film granularity or film defects such as dust, scratches, etc. The sanding operation explores the spatial derivatives and alters data values to restrain the derivatives to any specified limit. Further effort is required to determine the capabilities and limitations of this technique.

Task 4: Dual Gamma Studies. The dual gamma studies have been in progress for several months. The initial effort was directed toward the development of a mathematical model of the process. The first model explains the adjacency effect on the basis of a granular visualization in which, (a) there is a limited amount of developer present, (b) the number of grains developed in an increment of time is proportional to the quantity of developer available at that point in the image, and (c) the developer has some limited amount of lateral mobility so that small area shortages in developer are resupplied from adjacent developer, whereas large area shortages cannot be so resupplied.

This first simple mathematical model has been programmed on the computer in such a way that "latent images" can be subjected to this model of chemical processing. To date variable width bar images and a picture of the Capitol Building have been processed in this way. The adjacency effect is evident in the bar imagery.

The program of research outlined in this proposal is intended to maximize the yield during the 3-month period by taking full advantage of the progress which has been made to date and by performing those tasks which will have maximum benefit in terms of assessing the potential value and expectations of computerized image processing.

III. Technical Discussion

It is proposed that the program of research currently in progress under Contract [redacted] be continued for the 3-month period of July through September 1969. During the time period the effort will be directed to the following tasks:

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Task 1: On-Line Computer Operations. The software which has been developed over the past years is performing well. It is not anticipated that there will be any dramatic changes undertaken during this funding period. Continuing support will be required to add new transfer functions and other operations as the needs develop in the course of the basic restoration investigations. It seems likely that a substantial portion of the programming effort may be directed toward operations required to perform smoothing of edge discontinuities and elimination of unwanted background noise. Recent restoration experiments have tended to indicate the importance of the development of such techniques.

Task 2: Equipment Engineering. It should be emphasized that the equipment engineering task has had the goal of supplying input-output systems adequate to the performance of the processing research on an efficient basis. When the image processing research was initiated there were no suitable scanner and display systems commercially available. This is substantially true today. The culmination of this work is the refresh display system presently being repackaged for use with the computer. The only addition to this display which is presently contemplated is a light pen capability for communicating complicated addresses to the computer, as for example, outlining an object of interest in an image for the purpose of invoking background smoothing operations. If undertaken, the light pen will be funded by the Advanced Research Projects Agency and is not a part of the work to be funded in the present proposal.

The equipment engineering effort to be supported by funds responsive to this proposal will be limited to a continuation of the repackaging effort on the refresh display system. It seems highly probable that this task can be completed during the 3-month period covered by this proposal.

Task 3: Basic Restoration Investigations. A limited effort will be continued on the non-Fourier processing techniques described in previous proposals. It should be emphasized that these techniques are not an equivalent to Fourier processing. Therefore the goal is not an alternate technique for achieving the same results. The goal is better processing than can be achieved with Fourier processing by virtue of a more realistic treatment of film granularity and better utilization of a'priori knowledge.

Numerical definition of the extent to which image processing can be accomplished as a function of resolution and film granularity will receive major attention during the funding period. Such definition will be undertaken for both defocus and image motion degradation.

Image processing experiments will be undertaken on photograph images degraded by image motion. The resolution associated with the imagery will be increased incrementally starting with approximately 20 lines per millimeter and working towards a goal of 100 lines per millimeter. It is not possible to predict the resolution range which will be achieved during this 3-month period because this will depend entirely on how much time is required to achieve successful results at each of the lower resolutions.

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Task 4: Dual Gamma Studies. Examples of real dual gamma processed films and their conventional processed equivalents will be studied. The comparison of their Fourier transforms should indicate the extent to which the dual gamma processing has altered the imagery. An attempt will be made to computer process the conventional imagery using the dual gamma mathematical model to achieve results comparable to the actual dual gamma imagery. This will involve manipulating the several constants in the mathematical model in order to match the example of the real dual gamma processing.

Since the adjacency effects of dual gamma are spatially non-linear and heavily dependent on the local density gradients in the imagery, it would be expected that the effect would be most pronounced with sharp imagery and much less pronounced with badly degraded imagery. As an image enhancement technique it has the undesirable quality of failing under the condition where it is most needed. The mathematical model of dual gamma processing will be used to explore this premise, and will also be used to determine the extent to which the linear Fourier type image restoration can be employed as a function of the degree of adjacency present in the degraded imagery.

IV. Work Statement

Task 1: On-Line Computer Operations

1. Provide new transfer functions and/or other operations as required for performing the research.

2. Provide programs for background and edge smoothing operations.

Task 2: Equipment Engineering

1. Continue repackaging of the refresh display for computer use.

Task 3: Basic Restoration Investigations

1. Limited effort on the non-Fourier processing techniques.

2. Perform computer studies to determine the extent of processing possible as a function of film resolution and granularity.

3. Process motion degraded imagery starting with 20 lines/mm and moving toward 100 lines/mm.

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Task 4: Dual Gamma Studies

1. Compare dual gamma and conventional processed imagery of the same scene in both the spatial and spatial frequency domains.

2. Adjust the constants in the mathematical model of dual gamma processing and computer process the conventional picture in (1) to achieve the dual gamma picture in (1). This is a validation of the mathematical model.

3. Computer degrade an image, computer develop it with the dual gamma mathematical model, and perform normal image restoration operations to determine the extent to which the adjacency effects the restoration process.

V. Deliverable Items

1. A short interim report will be issued at the conclusion of each of the investigations described in Section IV. A final report will be written covering the 3-month's effort.

2. There is no deliverable equipment associated with the work described in this proposal.

VI. Performance Percentage Completion

	July	August	September	Total
Task 1:				
1	2.5%	5.0%	6.2%	
2	0.6%	5.4%	6.2%	12.4%
Task 2:				
1	6.4%	12.8%	19.0%	19.0%
Task 3:				
1	5.4%	10.8%	16.3%	
2	8.2%	11.6%	11.7%	
3	0	9.4%	27.4%	55.4%
Task 4:				
1	2.5%	3.9%	4.4%	
2	0.9%	4.4%	4.4%	
3	0	1.4%	4.4%	13.2%
	26.6%	64.7%	100.0%	

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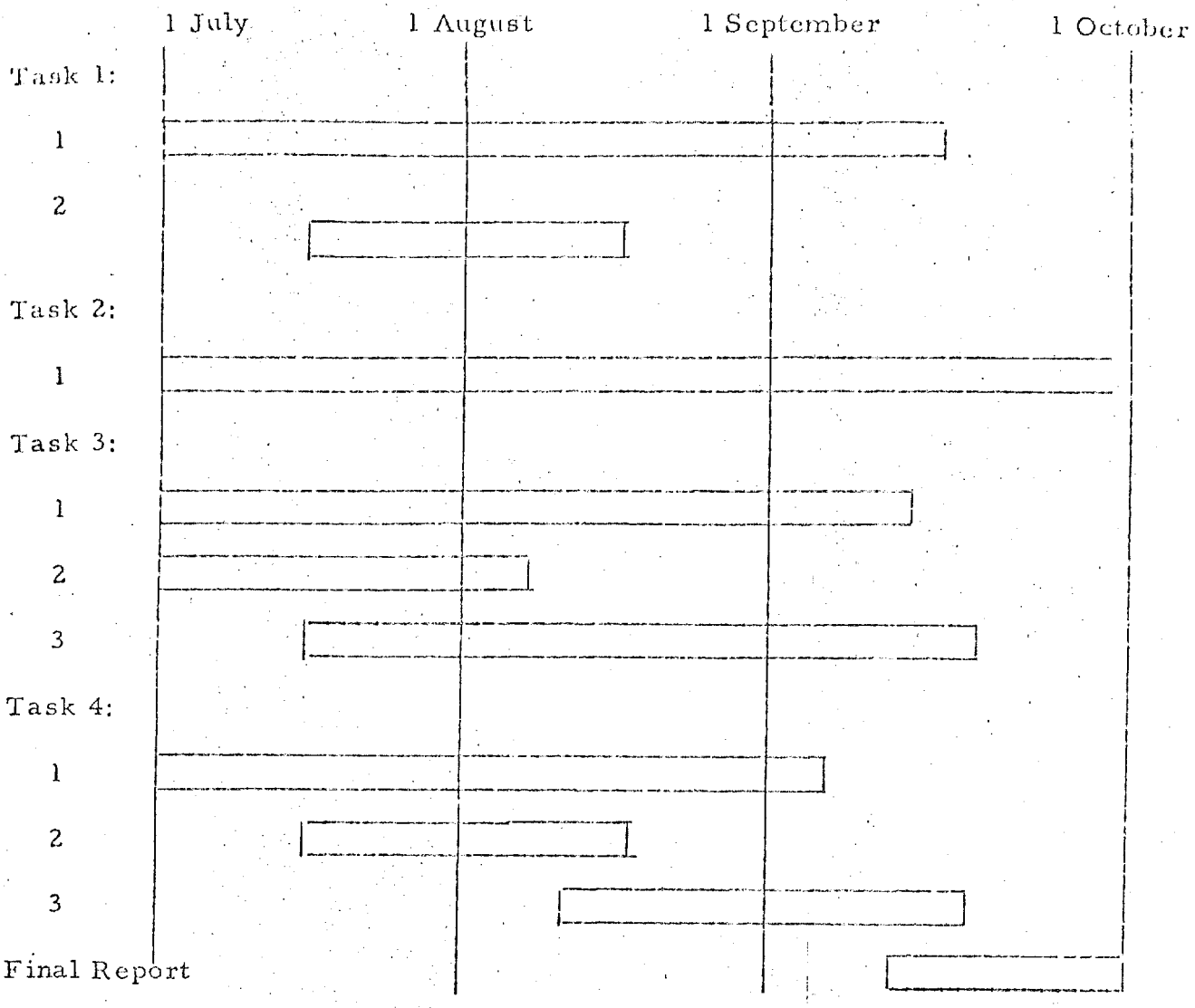
VII. Time Bar Chart



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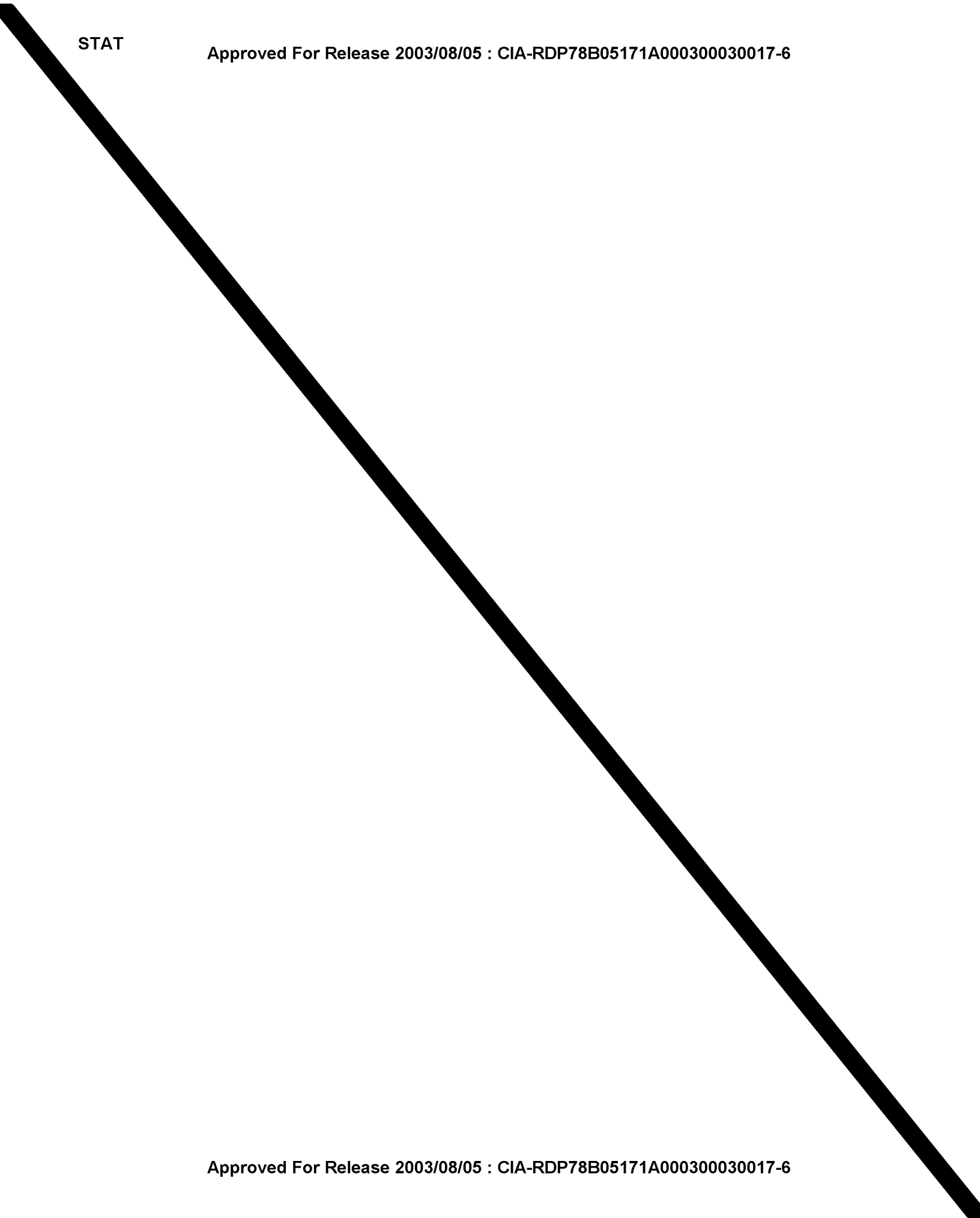

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